illustrates a schematic block diagram of such a transmission system. A serial data signal a is fed to a serial/parallel converter 1 ~~which~~that converts the serial digital data signal a into data packets with N/2 sub-packets, N being an even number. One data packet is transmitted in parallel to an encoder 2, which assigns each sub packet to a separate carrier frequency and supplies a first digital signal vector to an inverse Fourier transformer 3, which performs an inverse Fourier transformation on this vector and generates a second digital signal vector comprising N samples of a signal to be sent. This second digital signal vector is transmitted to a parallel/serial converter 23, which supplies the elements or samples of the second digital signal vector to a digital filter 24 followed by a digital-to-analog converter 25 and a line driver 26. The ~~thus~~ generated analog transmit signal is transmitted via a channel 27, whereby noise b is added, symbolized by an adder 28. On the receiver side, the signal is equalized by an equalizer/an analog-to-digital converter 29. Then the signal is decoded by performing the reverse operations of the encoding elements 1 to 23, namely through a serial/parallel converter 30, a Fourier transformer 31, a decoder 32, a slicer 33 and a parallel/serial converter 34.

Please replace the paragraph beginning on page 2, line 6, with the following rewritten paragraph:

Since the transmit signal is composed of a plurality of different signals having different carrier frequencies and amplitudes and phases being determined by the data signal and thus having no predetermined relationships, the amplitude of the transmit signal has approximately a Gaussian distribution. ~~Fig. 8 shows~~Figure 2 illustrates the probability h of the amplitude A of the transmit signal as determined by a simulation for a discrete multitone modulated transmit signal with a Fourier transform block length of 256.

Please replace the paragraph beginning on page 2, line 12, with the following rewritten paragraph:

Because of this Gaussian distribution, the crest factor of the signal is rather large, that is, the transmit signal has a rather high maximum amplitude value compared to the effective or average amplitude value. Since both the digital-to-analog and analog-to-digital converters, as well as the line drivers, have to be adapted to handle the whole possible amplitude range, these elements have to be defined accordingly causing additional costs and chip space. It is therefore desirable to reduce the crest factor, that is to reduce the maximum amplitude.

Please replace the paragraph beginning on page 2, line 19, with the following rewritten paragraph:

In principle, two different approaches are known to reduce the crest factor~~:~~.

~~1. M~~A first method for reducing the maximum amplitudes ~~which~~ disturbs the transmit signal.
These methods comprise clipping methods as described for example in US patent no. 6,038,261.

~~2. M~~A second method for reducing the maximum amplitude without disturbing the signal.

Please replace the paragraph beginning on page 3, line 1, with the following rewritten paragraph:

In general, these methods use one or more of the carrier frequencies to modify the transmit signal in order to reduce the maximum amplitude. The carrier frequencies used for this purpose may ~~not~~ or may not only partially be used for the actual data transmission.

Please replace the paragraph beginning on page 3, line 4, with the following rewritten paragraph:

One of these methods is described in the already cited US patent 6,529,925 B1. There, the Nyquist frequency is used as a single carrier frequency for correction purposes, that is, the last frequency in the inverse Fourier transform. In an ADSL signal, this frequency is not used for data transmission so that the correction does not influence the transmission capacity. However, the performance of this method is limited since only a single carrier frequency is used for correction. Furthermore, this method is not applicable to VDSL signals since the Nyquist frequency is outside the usable frequency range both for downstream and for upstream transmission.

Please replace the paragraph beginning on page 3, line 12, with the following rewritten paragraph:

In US 6,424,681 B1 a method for reducing the crest factor using a plurality of carrier frequencies is disclosed. These carrier frequencies are preferably evenly distributed over the whole usable frequency range. From these carrier frequencies a normalized correction signal, a so-called kernel, is generated which has a "Dirac"-like shape, that is, ~~which~~a shape that comprises a single peak as far as possible. To correct a transmit signal, this correction signal is phase shifted to the position of the maximum of the transmit signal and then scaled with a suitable scaling factor depending on the maximum amplitude of the transmit signal. Then, this correction signal is subtracted from the transmit signal. This can be repeated several times to iteratively correct several maximum or peak values. For transmission systems with a great number of carrier frequencies and consequently a great number of signal values in each frame, like a VDSL transmission system, this method is difficult to realize since it needs a relatively long computation time. Furthermore, through the use of a kernel, the carrier frequencies used for the correction have to comprise both low and high frequencies which, consequently, are not usable for data transmission. The use of low carrier frequencies, on the other hand, leads to a

greater loss of transmission capacity since lower carrier frequencies can be modulated with more bits than high carrier frequencies due to the lower damping.

Please replace the paragraph beginning on page 4, line 5, with the following rewritten paragraph:

SUMMARY

~~It is therefore an object~~ One embodiment of the present invention ~~to~~ provides a method and an apparatus ~~which~~that effectively reduce the crest factor using a limited number of carrier frequencies. Furthermore, ~~it is an object to provide~~one embodiment provides such a method and such an apparatus ~~which~~that are usable for VDSL transmission.

Please replace the paragraph beginning on page 5, line 2, with the following rewritten paragraph:

~~SUMMARY OF THE INVENTION~~

According to one embodiment of the invention~~,~~ for reducing the crest factor of a signal using a plurality of partial correction signals having predetermined frequencies, the following steps are carried out:

Please replace the paragraph beginning on page 5, line 17, with the following rewritten paragraph:

As for each of the predetermined frequencies, i.e. carrier frequencies, an amplitude and a phase is calculated, and it is possible to use the predetermined frequencies available in an optimum manner to correct the signal.

Please replace the paragraph beginning on page 6, line 11, with the following rewritten paragraph:

Therefore, instead of performing the above method on the signal or on a vector representing the signal, ~~it is preferred to~~one embodiment performs the method on a vector containing only a predetermined number of maximum amplitude values of the signal. This predetermined number may be significantly lower than the number of samples in the actual signal vector, therefore saving considerable calculation time while only marginally lowering the performance. To do this, the positions of the elements of the vector with the maximum amplitude values in the original signal vector have to be stored since the final correction has to be performed on the signal itself.

Please replace the paragraph beginning on page 7, line 1, with the following rewritten paragraph:

BRIEF DESCRIPTION OF THE DRAWINGS

~~Further features and advantages of the present invention will become apparent from the following description of preferred embodiments thereof, in connection with the accompanying drawings, wherein:~~

The accompanying drawings are included to provide a further understanding of the present invention and are incorporated in and constitute a part of this specification. The drawings illustrate the embodiments of the present invention and together with the description serve to explain the principles of the invention. Other embodiments of the present invention and many of the intended advantages of the present invention will be readily appreciated as they become better understood by reference to the following detailed description. The elements of the drawings are not necessarily to scale relative to each other. Like reference numerals designate corresponding similar parts.

Please replace the paragraph beginning on page 7, line 5, with the following rewritten paragraph:

~~Fig. 1 is~~Figure 3 illustrates an embodiment of an apparatus for reducing a crest factor of a signal according to the present invention~~,~~.

Please replace the paragraph beginning on page 7, line 7, with the following rewritten paragraph:

~~Figs. 2~~Figures 4A and ~~2~~4B ~~show~~illustrates simulations of the performance of the method of the present invention for ADSL signals~~,~~.

Please replace the paragraph beginning on page 7, line 9, with the following rewritten paragraph:

~~Figs. 3~~Figures 5A and ~~3~~5B ~~show~~illustrate further simulations of the performance of the method of the present invention for ADSL signals~~,~~.

Please replace the paragraph beginning on page 7, line 11, with the following rewritten paragraph:

~~Figs. 4~~Figures 6A and ~~4~~6B ~~show~~illustrate usable frequency ranges for VDSL in a downstream and in an upstream direction, respectively~~,~~.

Please replace the paragraph beginning on page 7, line 13, with the following rewritten paragraph:

~~Figs. 5~~Figures 7A and ~~5~~7B ~~show~~illustrate simulation results for VDSL upstream~~,~~.

Please replace the paragraph beginning on page 7, line 15, with the following rewritten paragraph:

~~Figs. 6~~Figures 8A and ~~6~~8B show simulation results for VDSL downstream~~,~~.

Please replace the paragraph beginning on page 7, line 17, with the following rewritten paragraph:

~~Fig. 7 shows~~Figure 1 illustrates a standard multi-carrier transmission system~~,~~. ~~and~~

Please replace the paragraph beginning on page 7, line 18, with the following rewritten paragraph:

~~Fig. 8 shows~~Figure 2 illustrates an amplitude probability distribution for a standard multi-carrier transmission system.

Please replace the paragraph beginning on page 8, line 1, with the following rewritten paragraph:

DETAILED DESCRIPTION

As already described in the introductory portion with reference to ~~Fig. 7~~Figure 1, a transmit signal in a multitone transmission like discrete multitone transmission comprises a number of samples derived from parallel processing of a number of bits of serial data, a data block. This transmit signal may be described as a vector

Please replace the paragraph beginning on page 8, line 6, with the following rewritten paragraph:

$$X^T = [x(1), x(2), ..., x(N)], \quad (1)$$

N being the number of samples and $x(n)$ being the respective samples, n ranging from 1 to N. The index n thus denotes the time position of the respective sample. "T" indicates that the vector in equation (1) is written in a line instead of in a column.

Please replace the paragraph beginning on page 8, line 10, with the following rewritten paragraph:

~~T~~One embodiment of the present invention is to determine a correction vector Xk so that the maximum absolute value or amplitude of the elements of the vector Xs with

$$Xs = X - Xk \quad (2)$$

assumes a minimum value. The correction vector Xk is a superposition of several partial correction vectors corresponding to a number of carrier frequencies or carrier tones reserved for forming the correction vector Xs, i.e.

Please replace the paragraph beginning on page 9, line 12, with the following rewritten paragraph:

1. determining the element of the vector X having the maximum absolute amplitude $|X(k\max)|$ and its position within the vector X $k\max$, and

Please replace the paragraph beginning on page 9, line 18, with the following rewritten paragraph:

3. For the carrier frequency μ, a partial correction is carried out according to:

$$x(k)_{new} = x(k)_{old} - g(\max\{xh(k)\} + \min\{xh(k)\}) \cdot 0.5 \cdot \cos\left(2\pi\mu \frac{k - k\max}{N}\right), \quad (6)$$

$$k = 1,2,\ldots,N,$$

wherein the indices "new" and "old" indicate that the elements of the vector X are replaced by the new elements. In equation (6), max is the maximum operator yielding the maximum value of all the $xh(k)$ and min is the corresponding minimum operator. In general, the minimum will be a negative value. It should be noted in this respect that the maximum absolute amplitude determined in step 1 may be either the maximum or the minimum value. The factor g is an appropriate converging factor which may be chosen to be 1 or may vary from iteration to iteration as explained below. The factors 0.5 and g may be drawn into a single factor.

Please replace the paragraph beginning on page 10, line 9, with the following rewritten paragraph:

4. ~~R~~also given is repeating steps 1 to 3 for all carrier frequencies μ used for correcting the signal, whereby the "new" vector X is used for the respective next carrier frequency.

Please replace the paragraph beginning on page 10, line 11, with the following rewritten paragraph:

5. ~~R~~also given is repeating steps 1 to 4 L times. The converging factor g can be chosen to decrease from iteration to iteration ensuring a better convergence.

Please replace the paragraph beginning on page 11, line 13, with the following rewritten paragraph:

1. the position $k\max$ of the element of the vector Xm having the largest absolute amplitude or value $|xm(k\max)|$ is determined and

Please replace the paragraph beginning on page 11, line 19, with the following rewritten paragraph:

2. an auxiliary vector Xmh according to

$$xmh(k) = xm(k) \cdot \cos\left(2\pi\mu \frac{pm(k) - pm(k\max)}{N}\right); k = 1,2,\ldots,M \qquad (7)$$

is calculated, wherein the xmh are the components of the vector Xmh. Thus, through the use of the vector Pm within the cosine term, the cosine term assumes the "correct" values for the elements of the vector Xm ~~which~~that correspond to the values of the correction finally performed on the whole signal X.

Please replace the paragraph beginning on page 11, line 21, with the following rewritten paragraph:

3. A partial correction corresponding to the one for the full vector X is carried out:

$$xm(k)_{new} = xm(k)_{old} - g \cdot (\max\{xmh(k)\} + \min\{xmh(k)\}) \cdot 0.5 \cdot \qquad (8)$$

$$\cdot \cos\left(2\pi\mu \frac{pm(k) - pm(k\max)}{N}\right); k = 1,2,\ldots,M.$$

Please replace the paragraph beginning on page 12, line 3, with the following rewritten paragraph:

After performing the algorithm the correction vector Xk for the signal vector, X has to be calculated. To this end, it is helpful to store for each partial correction and for each frequency μ the correction amplitude

Please replace the paragraph beginning on page 12, line 6, with the following rewritten paragraph:

$$\Delta u(i,j) = g \cdot (\max\{xmh(k)\} + \min\{xmh(k)\}) \cdot 0.5, \qquad (9)$$

Please replace the paragraph beginning on page 12, line 8, with the following rewritten paragraph:

$$\Delta p(i,j) = pm(k_{\max}), \qquad (10)$$

Please replace the paragraph beginning on page 12, line 11, with the following rewritten paragraph:

4. ~~Repeating~~Finally steps 1 to 3 are repeated for all carrier frequencies μ used for the correction signal or vector, and

Please replace the paragraph beginning on page 12, line 13, with the following rewritten paragraph:

5. ~~Repeating~~ steps are repeated 1 to 4 L times, possibly with decreasing converging parameter

g.

Please replace the paragraph beginning on page 12, line 1, with the following rewritten paragraph:

$$b_i(\mu) = \sum_j \Delta u(i,j) \sin\left(2\pi\Delta p(i,j)\frac{\mu}{N}\right).$$

Please replace the paragraph beginning on page 13, line 9, with the following rewritten paragraph:

$$b_i(\mu)_{new} = b_i(\mu)_{old} + \Delta u(i,j) \cdot \sin\left(2\pi\mu\frac{\Delta p(i,j)}{N}\right).$$

Please replace the paragraph beginning on page 12, line 9, with the following rewritten paragraph:

The correction vector is composed of cosine and sine values weighed with respective amplitude values. The cosine and sine values can be read from a sine table or a cosine table. One table is sufficient for the cosine and the sine values since its two functions only differ in the phase, that-is the respective address of the table read out has to be adapted. The use of such a sine table makes the algorithm faster compared to explicitly calculating the sine or cosine values each time.

Please replace the paragraph beginning on page 14, line 3, with the following rewritten paragraph:

$$c_i(\mu) = \sqrt{a_i^2(\mu) + b_i^2(\mu)}\,; \qquad \varphi_i(\mu) = \arctan\left(\frac{b_i(\mu)}{a_i(\mu)}\right). \tag{14}$$

Please replace the paragraph beginning on page 14, line 5, with the following rewritten paragraph:

In this case, only a single sine value has to be calculated or read out from the sine table for each partial correction vector with the carrier frequency μ. The values for $c_i(\mu)$ and $\varphi_i(\mu)$ from equation (14) may also be calculated using the known Cordic algorithm. This algorithm is

used for calculating amplitude of a phase of a complex number when its real end imaginary part is given. As a real part a_i and as imaginary part b_i can be taken. The Cordic algorithm is an iterative algorithm ~~which~~that uses only additions and subtractions as well as the sign function for determining the sine of a number. For performing the algorithm, L arcus tangens values have to be stored, L being the number of iterations of the Cordic algorithm. After carrying out the Cordic algorithm the amplitude of the respective complex number which results from the algorithm is enlarged by a fixed factor dependent on L. Therefore, it is necessary to divide this value by this factor. To be able to omit these divisions, the values of the sine table may be divided by the factor in advance.

Please replace the paragraph beginning on page 15, line 20, with the following rewritten paragraph:

1. The vector Xm is initialized to contain the M last elements of the vector X, ~~i.e.~~that is,

Please replace the paragraph beginning on page 16, line 1, with the following rewritten paragraph:

$$xm(k) = x(N - M + k); \qquad k = 1,2,\ldots,M. \tag{19}$$

Please replace the paragraph beginning on page 16, line 2, with the following rewritten paragraph:

2. The vector Pm is initialized accordingly, ~~i.e.~~that is,

Please replace the paragraph beginning on page 16, line 3, with the following rewritten paragraph:

$$pm(k) = N - M + k; \qquad k = 1,2,\ldots,M. \qquad (20)$$

Please replace the paragraph beginning on page 16, line 4, with the following rewritten paragraph:

3. A counter λ is set to 0: $\lambda = 0$.

Please replace the paragraph beginning on page 16, line 10, with the following rewritten paragraph:

$k\min = Position\ of\ \min\{|xm(k)|\}$; ~~i.e.~~that is,

Please replace the paragraph beginning on page 16, line 12, with the following rewritten paragraph:

$|xm(k\min)| = \min\{|xm(k)|\}$.

Please replace the paragraph beginning on page 16, line 13, with the following rewritten paragraph:

6. The counter λ is incremented: $\lambda = \lambda + 1$.

Please replace the paragraph beginning on page 16, line 16, with the following rewritten paragraph:

$|x(\lambda)| > x\min$.

Please replace the paragraph beginning on page 16, line 17, with the following rewritten paragraph:

8. When $|x(\lambda)| > x\min$ is fulfilled, the minimal element of the vector Xm is replaced by the element of the vector X designated by the counter λ, and the corresponding element of the vector Pm is replaced by λ, ~~i.e.~~that is,

Please replace the paragraph beginning on page 16, line 21, with the following rewritten paragraph:

$pm(k\min) = \lambda$.

Please replace the paragraph beginning on page 17, line 10, with the following rewritten paragraph:

~~Fig. 1 shows~~Figure 3 illustrates an apparatus suitable for carrying out the method of the present invention corresponding to the algorithms described above. A data signal a is supplied to a serial-to-parallel converter 1 and modulated onto a number of carrier frequencies wherein a predetermined number of carrier frequencies are not used for transmitting the data, but for building the correction signal as described above. On the thus generated signal, an inverse Fourier transform is performed in element 3, and the data is supplied to a parallel-to-serial converter 23, which is generally used for serially outputting the corresponding signal vector. Up to this point, the apparatus corresponds to the one already described with reference to ~~Fig. 7 in the introductory portion of this patent application,~~Figure 1 above, that is, in converter 23 the vector X is stored. The vector X is transmitted to means 4 for determining the maximum amplitude $x\max$ of the elements of the vector X. Comparing means 5 compare this maximum value $x\max$ with a given reference value $xref$. If $x\max$ is below $xref$, switches 6 and 7 are opened, meaning that no correction algorithm is performed as the maximum value $x\max$ is

below *xref* which represents a maximum tolerable value for the amplitudes or values of the vector X. In this case, the vector X is output via a subtractor 35 unchanged, since switch 7 supplying the negative input of subtractor 35 is opened.

Please replace the paragraph beginning on page 18, line 13, with the following rewritten paragraph:

It should be noted in this respect that the vector representation serves as a means for easily representing the signals. However, the whole procedure may as well be viewed as carried out using the signals themselves, ~~i.e.~~that is, emitting corresponding correction signals having the respective frequencies μ.

Please replace the paragraph beginning on page 19, line 3, with the following rewritten paragraph:

In the following, the performance of the method according to the invention will be demonstrated using simulation results.

Please replace the paragraph beginning on page 19, line 6, with the following rewritten paragraph:

For the inverse fast Fourier transform in ADSL systems generally 265 frequency values which are equally spaced from 0 to half the sampling frequency are defined. Therefore, a frame or vector X comprises 512 signal values, ~~i.e.~~that is, N =512. The distance between carrier frequencies is 4.3125 KHz, resulting in a sampling frequency of 2.208 MHz. For data transmission the frequencies numbers 33 to 255 are used (142.3 to 1100 KHz). Two different sets of parameters were simulated. The first simulation was performed using frequency numbers 254, 217, 247, 225, 239, 231, 210 and 243 for correction purposes. M was set to 8, L, the

maximum number of iterations, also to 8. *xref* was set to 4.1. The power of the signal was normalized to 1, so that the peak value corresponds to the crest factor.

Please replace the paragraph beginning on page 19, line 16, with the following rewritten paragraph:

~~Figs. 2~~Figures 4A and ~~2~~4B ~~show~~illustrates the results for these values. ~~Fig. 2~~Figure 4A ~~shows~~illustrates the probability p for the occurrence of various crest factors C given as a ratio, ~~Fig. 2B is~~Figure 4B illustrates the same graph with the crest factor c given in decibel. Curve 11 shows the theoretical Gaussian distribution. Curve 12 shows the result without correction. The reason why curve 12 deviates from curve 11 is the limited simulation time, for a longer simulation time also the even higher crest factors would eventually occur. It can be seen that crest factors above 5.5 occur with a probability greater than 10^{-8}.

Please replace the paragraph beginning on page 20, line 4, with the following rewritten paragraph:

For a second simulation, only five carrier frequencies were used for correction, namely numbers 240, 224, 208, 192 and 176. These five carrier frequencies are evenly spaced apart resulting in a periodic correction signal or correction vector Xk with a period of 32. M and L were both set to 8 as in the first simulation, and *xref* was set to 4.3. The result as ~~shown~~illustrated in ~~Figs. 3~~Figures 5A and ~~3~~5B corresponding to ~~Figs. 2~~Figures 4A and ~~2~~4B of the first simulation. Curve 11 again is the theoretical Gaussian distribution, curve 14 is the uncorrected curve corresponding to curve 12 of ~~Figs. 2~~Figures 4A and ~~2~~4B, and curve 15 is the corrected curve using the method of the present invention. The deviations between curves 12 in ~~Figs. 2~~Figures 4A and ~~2~~4B and curves 14 in ~~Figs. 3~~Figures 5A and ~~3~~5B again stem from the statistical nature of the amplitude distribution and the limited simulation time. In this case, a crest factor of 4.4 corresponding to 12.85 dB occurs with a probability of 10^{-8}. Here, still a reduction of 2.3 dB compared to the uncorrected curve is obtained.

Please replace the paragraph beginning on page 21, line 1, with the following rewritten paragraph:

For downstream and upstream transmission different frequency ranges are defined, which are ~~shown~~illustrated in ~~Figs. 4~~Figures 6A and ~~4~~6B. ~~Fig. 4~~Figure 6A ~~shows~~illustrates the frequencies reserved for downstream transmission corresponding to frequencies number 257 to 695 and 1182 to 1634. ~~Fig. 4~~Figure 6B ~~shows~~illustrates the frequencies reserved for upstream transmission, ~~i.e.~~that is, frequency numbers 696 to 1181 and 1635 to 2782.

Please replace the paragraph beginning on page 21, line 15, with the following rewritten paragraph:

~~Figs. 5~~Figures 7A and ~~5~~7B ~~show~~illustrates the simulation results, the representation of the results again being similar to those of ~~Figs. 2~~Figures 4 and ~~3~~5. Curve 11 again represents the theoretical Gaussian distribution, curve 16 the signal without correction and curve 17 the signal with correction according to the method of the present invention. A probability of 10^{-8} corresponds to a crest factor of 4.5 or 13 dB according to curve 17, which again is a considerable reduction compared to the 5.6 or 15 dB of the uncorrected curve 16.

Please replace the paragraph beginning on page 21, line 21, with the following rewritten paragraph:

For a downstream simulation, six carrier frequencies were used, namely frequencies number 1600, 1536, 1472, 1408, 1344 and 1280. The distance between the carrier frequencies again is 64, which again results in a periodic correction signal having a period of 128. For the simulation, the parameters $M = 32$, $xref = 4.3$ and $L = 8$ were used. ~~Figs. 6~~8A and ~~6~~8B ~~show~~illustrate the results of this simulation. Curve 18 is the result without correction, curve 19 is the result with the correction according to the present invention. A probability of 10^{-8}

corresponds to a crest factor of 4.65 or 13.4 dB, again yielding a significant improvement compared to the uncorrected signal.